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McGILL UNIVERSITY

Dept Applied Science

PAPERS FROM THE DEPARTMENT
OF
APPLIED SCIENCE.

No. 1.—PRESIDENTIAL ADDRESS.

BY

H. T. BOVEY, M.A., LL.D.

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MONTREAL, 1896.

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PRESIDENTIAL ADDRESS

BY

H. T. BOVEY, M.A., LL.D.,

McGILL UNIVERSITY

PRESIDENT, SECTION III., ROYAL SOCIETY OF CANADA.

I.—*Presidential Address.*

By H. T. BOVEY, M.A., LL.D., McGill University.

(Delivered May 19, 1896.)

GENTLEMEN,—In undertaking to give an address as president of Section III. I am conscious of attempting a task of great difficulty, for few men, in these days of specialists, can claim adequately and fairly to represent the claims of pure mathematics, chemistry, astronomy and physics in general. The only plan seems to be for each to speak for his own department, trusting that in this manner the work of the section will be covered in the course of three or four years. I have, therefore, thought it best to call your attention chiefly to the latest phase of engineering, namely, that of an experimental science, and especially to the close connection between actual practice and experiment, and the progress of invention, as illustrated by the modern history of engineering. You will, I doubt not, pardon me if I refer somewhat freely to the work now being carried on in the laboratories of McGill University, as, though fully conscious that this is but one of the busy workshops of the world, I am naturally most conversant with its details.

Some one has said that the birthday of modern engineering was the day when Watt announced his new discovery of the power of steam. It is, however, hardly fair to call it the birthday, it is more like the return of Rip Van Winkle. The science which built the pyramids, with their wonderful exactness of measurement; which planned the sculptured avenue for the rays of the midsummer sun; which constructed pools in Gihon and hanging gardens in Babylon; which warmed the houses of Pompeii and ventilated the tombs of Egypt—this science, I say, if it was really born in the eighteenth century, must have had a previous embodiment in far away times. Certainly, however, it has now entered upon a new phase, which has given it a fresh lease of free and wonderful life. It is as if the spark which had smouldered all through the dark ages, and fitfully gleamed, as it were, in the Gothic cathedrals, in Brunelleschi's dome and Giotto's tower—the perfect model of strength and beauty—had suddenly burst into a flame. There is no department of human life or industry which has not been illumined, and I do not hesitate to say that no one has done more than the engineer to advance the civilization of the world.

We begin to realize what was the state of affairs even after the middle of the last century, when we remember that it took from twelve to fourteen days to travel by stage coach from London to Glasgow, that in winter travelling was difficult and often impossible, that the cost of carrying a ton of coal from Liverpool to Manchester was as much as 40*s*., and the postage of a letter to Newcastle was 1*s*. No marked progress in any of the textile industries was possible for want of a motive power. Watt's application of steam was a turning point in the history of science, and caused an expansion so sudden and so far-reaching as to put to shame the wildest dreams of romance. Steam power began to be used in manufactures of all kinds, and production, thus rendered easy, was further stimulated by the greatly increased facilities of transportation. Trade took a fresh start, and hitherto undreamed of luxuries and comforts soon penetrated even into the most out-of-the-way places. A striking illustration of this progress came the other day in a private letter from a remote district of Africa, where a lady entirely isolated from civilization could yet telephone to a doctor for advice.

The successful utilization of steam as a motive power at once furnished an incentive to improve machinery. The spirit of invention was awakened and expended itself in devising machines, which grew in numbers and intricacy as the new conditions of life and the great increase of travel brought out new wants to be supplied.

In quick succession came Hargreaves' spinning jenny, Arkwright's frame, Crompton's mule, Cartwright's loom, and Eli Whitney's separator.

Some idea may be obtained of the enormous improvements thus caused in textile industries and the consequent expansion of trade, from the fact that in 1757 the exports of cotton from England were valued only at £45,000 sterling, while twenty-five years later the value was nearly 200 times as great. Simultaneously with this expansion of the textile trades, there was a great development in the mining industries, due to the discovery of gold and silver in new parts of the world and to the necessity of providing enormous quantities of coal to meet the demand of the motors, which began to increase in numbers to an almost incredible extent.

The marvellous advance in the number and complexity of machines is certainly one of the features of this century. This is very forcibly illustrated, even to the most casual observer, by the magnificent collection of Reuleaux' kinematic models in the museum of McGill University. These mechanisms give rise to an endless variety of interesting problems, and one of these is dealt with at the present meeting in a note by Professor Guest on "The Method of Mechanically Tracing the various Conic Sections."

Every kind of machine seems to have been brought into use for the supply of the numberless wants of people who so lately took their first lessons in luxury. We must now have our newspapers left at our door twice a day, so a linotype must do everything short of writing the articles, and a press must give out, cut and folded, 25,000 copies of the "Times" per hour. Even hand sewing has gone out of fashion, and although we are not prepared to use with respect to sewing the words of Sir W. Fairbairn, that "at the beginning of the century the human hand performed all the work that was done and performed it badly," this statement is certainly very true in reference to a large amount of work which is now done mechanically. Mechanical skill again has enabled surgery to do much for the alleviation of human suffering by the making of stethoscopes, microscopes and other delicate instruments, and by the invention of apparatus for straightening distorted limbs. On the other hand, perhaps in case too many people should be left alive. military science has been helped to make dynamite. and has been presented with torpedo boats and with Nordenfeldt and Maxim guns, the detonation of which, if we may trust newspaper reports, is warranted by a distinguished man of science to reduce the crews of two hostile men-of-war to mental imbecility in the space of fifteen minutes.

Although at the beginning of this century there was already such a marked advance in the application to machinery of steam as a motive power, there was no corresponding progress in its application to the improvement of the method of travel. The ship had still to wait for the wind, and the lumbering stage coach was dragged by the weary horse.

As early as the sixteenth century an attempt was made to apply steam to boats, and in 1736 the first patent was taken out. Towards the close of the last century a small steamer attained a speed of seven miles an hour on a loch in Dumfrieshire; in 1807 Fulton's steamer sailed from New York to Albany, and in 1819 the first steamer sailed from Liverpool to Dublin. From this time forward steam navigation grew fast, and in 1838 the Atlantic was crossed by steamers. To Canada belongs the undying honour of having built and equipped the "Royal William," the first steamship to cross the Atlantic. She was of 1370 tons burden, was built by George Black in Campbell's shipyard, Wolfe's Cove, Quebec, was launched on April 27th. 1831. and cost £16,000. She was towed to Montreal, where she received her engines, and sailed from Pictou, Nova Scotia, on August 17th, 1833, arriving at Gravesend on September 11th. She was sold to the Spanish Government in the following year, and was the first war steamer possessed by the Spaniards.

Steamships now rapidly increased in numbers and size, culminating in the "Great Eastern," more than one-eighth of a mile long and having a beam of 83 feet and a burden of 19,000 tons. The "Great Eastern" did not prove a commercial success, and, after running for a few years and having cost more than a million pounds sterling, she was sold for £16,000, and was broken up for scrap iron, much of which has been distributed throughout Canada in the form of nails. In the grand conception of the "Great Eastern" the engineer, Brunel, seems to have been just thirty-six years in advance of his time, the projected new steamship "Gigantic," of the White Star line, being a little longer.

The increase in the size of vessels has necessitated a corresponding enlargement of docks and wharfs at the great termini of commerce, as, in order to render the trade profitable, it is of the highest importance that the modern ocean palaces should be received, docked and started again with the least possible delay.

Owing to the keen competition in trade, every effort has been made by rival companies to secure a maximum of economy in fuel. In the early days the charges for transportation were so high that large profits were obtained with only low pressures of from 20 to 30 lbs., and a corresponding consumption of from 5 to 10 lbs. of coal per indicated horse power, but now it is not uncommon to have a working pressure of from 180 to 200 lbs., while the consumption of coal is less than 1½ lbs. per indicated horse power.

Very little progress has recently been made in the theory of the steam engine, and the problem now to be faced is one of great difficulty, and worthy of the attention of the most skilful analysts and physicists.

The laws of the expansion of steam in non-conducting cylinders, as investigated by Clausius and Rankine, are known not to be even approximately correct when applied to the actual engine. This was long concealed from view, for the reason that, even under the most diverse conditions as to the supply of heat during expansion, the curves of expansion of the steam, when the pressure and volume are taken as co-ordinates, are hardly distinguishable the one from the other. In 1889, however, Macfarlane Grey read a paper on "The Rationalization of Reynault's Experiments" before the meeting of Mechanical Engineers at Paris, and showed expansion curves of steam, with the temperature and entropy as the related quantities. From that time increased attention has been directed to the subject, and the extraordinary effect of the walls upon the form of the expansion curves thus represented has also been made clear.

Owing to the intricacy of the phenomena of the condensation and re-evaporation of steam during admission, expansion and exhaust, the consumption of steam, as estimated by the ordinary theories, is liable to an error of from 30 to 40 per cent. This can hardly be a matter of surprise when the complication of the phenomena is considered. Very little is yet known as to the rate of condensation of steam of different densities and different states of dryness on surfaces very various in character, *e.g.*, surfaces black or polished, or covered with an oil film, and again surfaces on which water is precipitated in drops or as a thin film. Kirsch has applied the Fourier analysis to the general problem of the flow of heat in an engine cylinder, but the experimental constants necessary for even the preliminary application of his results are quite lacking.

A few years ago Professor Hall, of Harvard, attempted, by means of thermo-electric junctions, to study experimentally the nature of the flow of heat, both steady and cyclical, in the metal walls of an engine cylinder, but his methods were open to serious sources of error.

During the summer of 1895 Professors Callendar and Nicolson, of McGill, carried out a preliminary research on the same subject, with a Robb-Armstrong simple non-conducting engine, using naked platinum thermometers in the steam and thermo-electric junctions and platinum thermometers in the walls. They obtained results which differed widely from those of Hall and others, and which showed surprising and unexpected relations between the phenomena. These results are now in course of preparation for publication.

During the succeeding winter an elaborate series of about fifty experiments was carried out by Professor Nicolson, and it is expected that these will throw much light on the above subject. The primary object was the study of the relative plant efficiency of compound triple and quadruple engines, but all the data for the study of cylinder condensation were also observed and recorded. In these experiments Prof. Nicolson had the advantage of the collaboration of Mr. A. L. Mellanby, a royal exhibitioner from the Durham College of Science, England, who is to read a paper at this meeting on the results of the experiments, more especially with regard to plant efficiency. These experiments were made with the 100-horse power engine of the thermodynamic laboratory in the W. C. McDonald Engineering Building—an engine erected solely for the purposes of such research.

Although at the end of the first quarter of the present century great progress had been made in ocean navigation, very small had been the corresponding advance in the direction of more rapid transit by land. But in 1830 George Stevenson's "Rocket" inaugurated the new and marvellous development in steam carriages. Europe and America have been covered with a network of railways, which have enabled the Atlantic and Pacific to join hands, which have climbed the wild gorges of the Rocky Mountains, and are now traversing the lonely plains of Siberia. In 1845 there were only 2,400 miles of railway in operation in Great Britain, and the amount of capital invested did not exceed £88,000,000 sterling. To-day there are more than 20,300 miles, and in his address as president of the Institute of Civil Engineers, Mr. Giles gives the gross returns of the traffic as amounting to a sum of not less than £82,000,000 per annum, a sum almost as great as the total capital invested fifty years ago, and representing the carriage of 900,000,000 passengers, 310,000,000 tons of goods and minerals, and about two and a half billions of letters and parcels. In America, again, in the year 1845, there were only 4,377 miles of railway, while at the beginning of the year 1895 there were no less than 232,755 miles in operation, and the capital invested amounted to

$11,455,220,000. With this enormous development there has also been a steady improvement in the appliances for the safety and comfort of passengers, and the luxury of travelling has touched a high point in the vestibuled trains of this continent.

What is it that has made it possible to develop railway traffic to such an enormous extent both as to speed and safety? The answer to this question involves the knowledge of the great revolution in engineering due to the discovery of the practicability of applying electricity to the transmission of messages over long distances, first by means of the electric telegraph. and more recently by means of the telephone. I have heard old Canadians tell of days when a conductor, in out-of-the-way places, not meeting a train at the proper crossing-point and not willing to wait an indefinite time, decided to take the risk and go on, trusting to good fortune that he should reach the next station before the belated train had passed it. The passengers, I suppose, held themselves in readiness to jump. Do we realize in how different a position we are placed to-day, when the electric telegraph flashes along the line the exact position of the train? The block system—in spite of our vaunted progressiveness. not yet in universal use on this continent—has been brought to such a pitch of perfection in England that even a mistake on the part of the signalman—the only thing which could vitiate its usefulness—is practically made almost an impossibility by means of mechanical contrivances which check and regulate his signals. The increase in the safety of railway travelling since the introduction of these improvements may be judged by figures given by Mr. Preece in an address before the members of the British Association at Bath, in which he says that in the five years ending in 1887 only one person was killed in 85,000,000 railway journeys.

The first practical instrument for the transmission of messages was devised by Cooke and Wheatstone in 1837. and in 1838 it was given a trial on the Great Western Railway.

It is very curious to look back sixty years and read an advertisement of the wonders of the Electric Telegraph posted up by the Great Western Railway Company :—

The Wonder of the Age!
Instantaneous Communication!
Under the special patronage of Her Majesty and H.R.H. Prince Albert
The Galvanic & Electro-magnetic
Telegraphs
on the
Great Western Railway
may be seen in constant operation, daily, (Sundays excepted) from 9 till 8
at the
Telegraph offices, London Terminus, Paddington, and Telegraph Cottage, Slough Station.

An Exhibition admitted by its numerous visitors to be the most interesting and attractive of any in this great metropolis.

In the list of visitors are the illustrious names of several of the Crowned Heads of Europe, and nearly the whole of the Nobility of England.

"This Exhibition, which has so much excited public attention of late, is well worthy a visit from all who love to see the wonders of science."—*(Morning Post)*

The Electrical Telegraph is unlimited in the nature and extent of its communications. By its extraordinary agency a person in London could converse with another at New York, or at any other place however distant, as easily and nearly as rapidly, as if both parties were in the same room. Questions proposed by visitors will be asked by means of this apparatus, and answers thereto will be instantaneously returned by a person 20 miles off, who will also, at their request, ring a bell or fire a cannon in an incredibly short space of time, after the signal for his doing so has been given.

The electric fluid travels at the rate of 280,000 miles per second.

By its powerful agency murderers have been apprehended (as in the late case of Tawell); thieves detected; and lately, which is of no little importance, the timely assistance of medical aid has been procured in cases which otherwise would have proved fatal.

The great national importance of this wonderful invention is so well known that any further allusion here to its merits would be superfluous.

N. B.—Despatches sent to and fro with the most confiding secrecy. Messengers in constant attendance, so that communications received by telegraph would be forwarded, if required, to any part of London, Windsor, Eton, etc.

Admission,—One Shilling.

As soon as the world had grasped the idea of the remarkable results of the electric telegraph, it cannot be wondered at that the attention of scientific men was called to the possibility of applying electricity to the transmission of sound itself. The result, in the evolution of the telephone, is too recent and too well known to require any description. It is evidently so much better adapted to the wants of city life than is the telegraph, that already the number of telephone messages as compared with telegraphic messages is as ten to one on this continent, where a careful estimate gives the number of 75,000,000 telegrams as compared with 750.000.000 telephone messages.

This electricity, which has effected so enormous a saving of time in the transmission of intelligence, as already indicated, has been still further utilized in this direction by the development of the electric motor. Ten years ago there was no such thing as an electric railway in our cities; now, we have so many railways that it may soon be a little doubtful whether we have any streets. The importance of the introduction of the electric railway can scarcely be overestimated, as it bids fair to solve some of the terrible problems of over-crowded city populations.

Not only is the motor valuable as a means of rapid transit, but its use secures great economy in centralizing the production of power. Small stations at many different points may be supplied with power from a wire, and the evils of smoke, soot and dust confined to a single point.

Already in street railway work the electrical energy utilized amounts to no less than one and a half million H. P., while the total dynamo capacity of the world, including the motor power required for street railways. has reached 5.000.000 H.P., and is rapidly increasing. Indeed, with the perfecting of the alternating motors, all obstacles to the transmission of power seem to have been overcome.

The economical transmission of electrical energy to a distance of 50 or 100 miles is an accomplished fact, and in the electrical exhibition now being held in New York, there is being daily demonstrated the practicability of bringing into that city over a distance of 450 miles, power generated by the Falls of Niagara. It is also freely stated that within a very few years from the present time, the greater part of the Pennsylvania Railroad system will be operated by electrical locomotives, so thoroughly convinced is the company that the electric service will prove economical and far superior to steam in efficiency. Thus, just as steam locomotion has reached its present pitch of perfection, it seems as if in a very short time it will be entirely superseded, and that the present locomotive will be found only in museums amongst the relics of the past.

As an illustration of electrical energy carried to a distance, I am enabled by the courtesy of Dr. Coleman Sellers, the consulting engineer of the Cataract Construction Company and also president and chief engineer of the Niagara Falls Power Company, to give some interesting details respecting the remarkable work now being carried on at Niagara.

So far as the main power station is concerned, the object has been to create a plant for distributing power. (1) to establishments located in the neighbourhood on the lands controlled by the company; (2) to railway and street lighting companies at or near Niagara Falls; (3) to power distributing companies located at distant points. The plant as now completed has a capacity of nearly 16,000 electrical horse power, but is arranged to be extended to 50,000 or even 75.000 horse power, as the growth of the business may warrant, the whole available capacity of the tunnel as a discharge or tail race being adapted to 100.000 horse power.

The present plant which is now in successful operation, consists of three turbines each driving a dynamo capable of delivering 5300 electrical horse power, and its extension by the erection of other units of like capacity is about to be made.

In order to insure the most economical condition for power independent of the question of lighting, the company has adopted the two-phase alternate current system of 25 full alternations per second at a primary voltage of 2200 volts. The bus bars from which the current is distributed are sized on a current density of about 1000 amperes per square inch.

The total head of water is about 212 feet. Of this head, 136 feet, measuring from the upper water level to a point midway between the two turbines which drive each dynamo, is the actual head of the water wheels in the power house. Such establishments as require wheels under their own control can use about 140 feet of head, if the character of the wheels used is such as not to be seriously affected by back water. Seventy-five feet represents the head devoted to the tunnel output at about 26 feet per second, or a hydraulic slope of 7½ feet per 1,000 feet.

There are many novel features in the hydraulic as well as in the electrical part of the power plant. The water wheels, two to each unit, are 6 feet in diameter, each wheel being divided into three parts and the speed being controlled by ring gates outside the wheels, which discharge the water radially. The water wheels have, after some slight alterations, been working very satisfactorily. The transmission of the power from the wheels is effected by means of hollow shafts made of quite light steel, 38 inches in external diameter, but contracted to solid shafts of 11 inches in diameter at those places where the bearings, steadying the shafts, are located. The experience with the bearings resulted in changes worthy of attention. On the recommendation of Dr. Sellers the bearings are continuous in surface and so lubricated as to insure a constant film of oil between the bearing and the shaft. The bearings are also lined with babbet metal of very superior quality, not for economy, but from actual experience as to the utter impossibility of running shafts in bronze bearings without babbet metal at 700 feet per minute surface velocity, with any certainty of their not cutting. They now run continuously without heating.

The whole plant is said to have worked remarkably well since August, 1895, and the demand for power has been so great among manufacturers in the immediate vicinity, as to leave no surplus power available for transmission to Buffalo out of the 15,000 electrical H.P. developed by the present installation. All the current now available from three dynamos is being utilized within one mile of the station. Beyond the power required to drive the local lighting and tram-road power stations, the current has been taken by establishments erected for metallurgical purposes, using large amounts of power but employing very few men, as is notably the case with the Pittsburg Reduction Co., manufacturing aluminum, the Carborundum Co., making a new abrasive material in large quantities, the Calcium Carbide Co., and other electro-chemical industries.

The dynamos were designed and built by the Westinghouse Electric & Manufacturing Co., of Pittsburg, Penn., making use of the rotating field suggested and patented by Prof. George Forbes, and the mechanical features proposed and secured to the Power Company by Dr. Sellers. An important consideration in this case was that the successful governing of the machinery depended upon a certain amount of fly-wheel effect, which was specified to be wholly accomplished by the revolving parts of the dynamo and not by a separate fly-wheel.

The governing of the machinery has been highly successful and this has been favoured by the Westinghouse Company's judicious arrangement of the material acting as a fly-wheel, whereby more fly-wheel effect is obtained than was deemed absolutely necessary by Messrs. Faesch and Piccard, the designers of the turbines, who called for a minimum effect of $PV^2=1{,}100{,}000{,}000$, whereas the Westinghouse Company succeeded in obtaining a fly-wheel effect of $PV^2=1{,}274{,}000{,}000$, within the limit of weight to be balanced by the water, P being the weight in lbs. at the radius of gyration of the revolving parts, and V the velocity in feet per second.

One of the interesting features connected with the design of the dynamo was the discovery by the Westinghouse Co. that for the field ring, a nickel steel containing a smaller proportion of nickel than is usual for armour plates, etc., proved to be particularly well qualified magnetically for this use, the steel serving a better purpose than the best iron.

The revolving parts of the dynamo and of the water wheel, taken conjointly, weigh 160,000 lbs., and this weight is carried entirely by water pressing against as much of the surface of the upper water wheel (there being two wheels to each machine) as is necessary to support the weight. There is only about 6,000 lbs. difference between the maximum and minimum upward pressure, so that when the dynamo is running with no load there is an upward pressure against the rings of the collar thrust equal to about 3,000 lbs., and when running at full load, there is a downward pressure of about 3,000 lbs. At 3,500 horse power, the vertical shaft is perfectly balanced by the water and there is no pressure whatever upon the rings of the thrust bearing.

In Mr. Stillwell's paper in "Cassier's Magazine" of July, 1895, it is stated that it was very fortunate that when these machines were designed the Bethlehem Iron Company had perfected their largest forging press, which at that time seems to have been the largest in the world, and which enabled them to turn out the nickel steel field rings forged without a weld, 11 feet 7½ in diameter, and having a width on the face of about 50 inches. They were forged from nickel steel ingots 54 inches in diameter at the bottom, 197 inches long, and weighing about 120,000 lbs., these being cast solid and compressed by hydraulic pressure after the manner proposed by Sir Joseph Whitworth. The ingot had a hole bored through its internal axis and a block of proper weight was thus taken from it, when it was expanded on a mandril under a 14,000 ton hydraulic press. It was rough turned by the Bethlehem Company and finally finished at Pittsburg by the Westinghouse Company. Not only are the physical properties of the ring extraordinary, and its size without precedent, but to those interested in the remarkable improvement in the quality of steel and the methods of working it, the value which attaches to this ring as an example of the finished product of the Bethlehem Iron

Company is not less than that it derives from the important part which it sustains in the Niagara installation. The speed of the ring at its periphery is 9,300 feet when making 250 revolutions per minute.

It has been found that the governor controls the speed so well that even if the whole load of 5000 horse power be thrown off instantly, the nominal speed of 250 revolutions only increases to 300 revolutions, and settles back to 252 in less than 20 seconds, the perturbation being over in less than 27 seconds. The guaranteed effect of the governor was to keep the speed within two per cent of the nominal speed at all times, and that if one quarter load be thrown off or on, the speed should not vary more than 4 per cent. In point of fact, under these conditions, with one quarter load thrown off or on, there is only a little over 3 per cent variation in speed.

The switchboard equipment in the power house is unique, one of the remarkable features being the Westinghouse design of main switches not intended to be used except in case of great emergency, but which can be operated to interrupt the current of 5,000 horse power, without any sparking or sensible rise in potential. The fuse blocks also have been reduced to occupy small space. The bus bars for five dynamos are made cylindrical, of copper tubing decreasing in size from the central section, adapted to the whole current of the output of five dynamos, all with lateral conductors insulated by the best rubber covering.

The transformation of the alternating current into direct current for the Pittsburg Reduction Company is accomplished by machinery built by the General Electric Company of the United States, which also designed the machinery required by the Carborundum Company, to obtain a variable potential reducing from 2200 volts to the minimum required in the work.

I have dwelt somewhat fully on the details of this great undertaking, as showing the close connection which is now maintained between theory and practice, each great engineering enterprise being regarded as an experiment on a larger scale than would otherwise be possible, from which we may derive new principles of action.

It is impossible to refer even briefly to the numberless purposes to which electricity is now applied. The advance in electric lighting has been most remarkable, and has conferred an enormous boon in giving us light without much heat and without the destruction of the life-giving properties of the atmosphere. It bids fair to revolutionize the heating and ventilating of our dwellings and the cooking of our food. It seems to do everything from ringing our bells and regulating our clocks, to the exploding of submarine mines and the firing of large ordnance. I cannot, however, leave the subject without a glance at the newest and most remarkable application of electricity to the production of kathode rays, by which photographing through opaque substances has been made possible.

Within a few days of the arrival of the news of Dr. Roentgen's discovery, Professor Cox of McGill University was able to photograph the bones of the hand, with one of the Crookes tubes belonging to the Physics Building. On February 7th, he succeeded in making the first applications of this process to surgery, on this continent, by photographing the location of a bullet in the leg of a patient. An account of the experiments and of the extraction of the bullet, is given in the *Montreal Medical Journal*, March. 1896.

Since that date, he has been engaged, in conjunction with Professor Callendar, in investigating the conditions of the production of the Roentgen rays, and the best method of obtaining clear and quick photographs.

The McDonald Physics Building was fortunately well equipped with mercury pumps, and with all the apparatus necessary for making and exhausting high vacuum tubes. When it was found that of the fifty Crookes tubes in the laboratory only two were sufficiently exhausted to take photographs, and that somewhat feebly, the mercury pumps were set in action as soon as the rare intervals of lecture work would permit, new tubes were made and old tubes re-exhausted to satisfy the urgent appeals of the medical profession. Several successful photographs were taken, showing the location of bullets and needles, and the nature of fractures. Concurrently with these practical applications, experiments were made to verify the properties and nature of the kathode rays as determined by Lenard and Roentgen, and to find the best form of tube to use, and the best conditions for taking kathode photographs and for seeing through the body with the fluoroscope.

Of all the Crookes tubes, that known as the "Focus" tube proved to be by far the best in point of quickness, clearness and penetration. In this tube, the kathode rays are brought to a sharp focus on a plate of platinum ; the rays proceeding from this focus-point in straight lines are of great intensity and cast very sharp shadows. In the form of tube commonly advertised and sold in this country, the rays are projected on to the glass wall of the tube, and the focus cannot be made sharp or much power employed for fear of melting the glass. This is the reason why Edison, Tesla, and others in the States have achieved such poor results as compared with those obtained in Europe, where the focus tube has been largely used. Some of the results obtained with a focus tube made and exhausted in the McDonald Physics Building will be exhibited in Section III. They include photographs of the skull and of the thickest parts of the body taken with exposures of one quarter to half an hour. Some of these show clearly buttons, hooks, etc., which were separated from the photographic plate by a thickness of six or eight inches of solid flesh and bone.

In a vacuum, the kathode rays are subject to magnetic influence, but Lenard has shown that, once in the air, they are unaffected by it. The principal reason which led Dr. Roentgen to the conclusion that he had discovered a new kind of ray was that he was unable to observe any deflection of the ray by a magnet. Experiments in the McDonald Physics Building, however, clearly prove that the Roentgen rays are really subject to magnetic influence in a vacuum as distinctly as are the kathode rays. The Roentgen rays and the kathode rays, therefore, behave alike ; in vacuo both are subject to magnetic influence, in the air both are unaffected.

On seeking to verify this result by observing the movements of the boundary line between the dark and bright parts of the bulb, by means of the fluoroscope, a surprising fact was established. At each reversal of the magnet, the image of the boundary line seen in the fluoroscope moved in precisely the opposite direction to that of the boundary line between light and darkness on the tube itself. The kathode rays indicated their presence by fluoroscence upon the glass ; the Roentgen rays by lighting the fluoroscope. The experiment proves that when the kathode rays are driven one way by the magnet, the Roentgen rays are driven in the opposite direction. This result was verified by taking a photograph of the boundary line with the magnet in reversed positions, when the two images of the boundary were found to be separated by nearly an inch.

Indirect reference has been made in the description of the works at Niagara Falls to the enormous importance of water power in engineering. Perhaps it may not be out of place to raise a note of warning as to the danger of practical science so magnifying the idea of utility as entirely to lose sight of the value to our race of natural beauty. Should the grandeur and beauty of the Falls of Niagara—which have stimulated thousands of men and women to loftier aspirations—be seriously interfered with, it might well be that the loss to the soul of humanity would be greater than its material gain.

That both ideals can be kept in view has been well shown in one of the greatest engineering triumphs of the day. In obtaining a proper water supply for the city of Liverpool, a singularly beautiful artificial lake in the midst of Vrynwy valley in the Welsh mountains has been created. Would that as much could be said for the supplying of water to the city of Manchester by utilizing the lovely natural lake of Thirlmere !

These works are also a good exemplification of the great benefits conferred by engineers in the providing of an absolutely uncontaminated water supply. That they are not called upon to do so more universally, that we are still content to drink water pumped up from a river polluted to a greater or less degree with the sewage of the villages and towns on its upper reaches—is nothing more nor less than a relic of the dark ages.

The proper disposal of sewage and town refuse opens a wide field for the chemical and agricultural engineer ; a problem not finally solved even by so great a project as the Chicago Sanitary Canal, probably the most important piece of engineering work at present under construction.

Its real object is to relieve the city of Chicago and the contiguous territory of sewage. though it is also to be used as a ship canal. To give an idea of the magnitude of its conception. I may state that its section is greater than that of either the Manchester, the Suez, or the North Sea ship canals. The depth of the water is to vary from a minimum of 22 feet to a maximum of 26 feet. The canal will be thirty-five miles in length, will be formed by the excavation of nearly forty million cubic yards of material, and will cost from twenty-seven to twenty-eight millions of dollars.

River improvements and hydraulic schemes of all kinds involve problems of great difficulty, which can only be solved by long experience and observation, and by intricate and delicate experiments. Professor Osborne Reynolds, at the meeting of the British Association in 1887, presented an important report. in which he showed that it is possible by means of experiments on a small scale to deduce certain laws relating to the régime of rivers and estuaries which "seem to afford a ready means of investigating and determining beforehand the effects of any proposed estuary or harbour works." Before allowing the construction of piers and dykes, would it not be well to require that preliminary experiments should be carried out. on the lines indicated by Reynolds, as to what would be the certain result of such works upon the water-way—especially when we consider the enormous interests often involved ?

A serious source of difficulty in our northern rivers is the presence of frazil and anchor ice during the winter. It seems strange that no systematic attempt has hitherto been made to investigate the conditions under which it is produced, or to find out whether any means could be adopted of preventing its formation in the neighbourhood of machinery driven by water power. With this object in view, during the months of February and March, Mr. H. T. Barnes, M.A.Sc.. made a preliminary series of observations with a Callendar electrical thermometer to determine the variations in temperature of the water of the St. Lawrence, and the results are fully described in a paper which will be read at the present meeting. It was found that even in the most severe weather the temperature of the water did not fall more than the one-hundredth of a degree below 32° Fahrenheit. Thus the formation of frazil is apparently not due to a lowering of the temperature but to radiation.

In connection with the subject of hydraulics, I may state that in 1894 and 1895 a lengthy series of experiments was carried out by myself with a view to determine with greater accuracy and wider scope than had hitherto been done the co-efficients of discharge for jets flowing through orifices of various forms.

These results have now been published. but certain sources of error having been subsequently eliminated, the experiments have been continued by Mr. Farmer, who has extended his researches to the investigation of the impact efficiency of jets impinging upon flat and curved surfaces. These results are presented in a paper at this meeting.

In the course of these experiments observations were also made on the phenomenon known as "the inversion of the vein," which was first studied by Bidone and subsequently by Magnus, Buff and Lord Rayleigh. The common explanation of this phenomenon is that the fluid particles issuing along different parabolic stream-lines impinge upon each other, and by their mutual reactions cause the jet to spread out and assume sectional forms depending upon the shape of the orifice.

A theory which seems more fully to account for the whole of the facts is that the peculiar changes in form are really due to surface tension and to the differences between the atmospheric pressure and the internal pressure of the jet.

In the case, for example, of a jet flowing through an elliptical orifice with the major axis vertical, the stream-lines in the vein are convergent and mutually react upon each other, causing the jet to contract vertically and elongate horizontally at a rate gradually increasing to a maximum, when the section is a circle in form.

At this stage the rates of elongation and contraction are the same. The elongation and contraction still continue, but at a diminishing rate, until the movement is stopped by the effect of surface tension, when the section is again elliptical, with the major axis horizontal and the minor axis vertical. The new major and minor axes then again begin respectively to contract and to elongate, the section of the jet passing through the circular form to its initial elliptical form.

This process is repeated over the whole length of the unbroken jet, and, in fact, in this portion of the jet the surface tension produces an effect similar to that which would be produced if the jet were surrounded by an elastic envelope.

The determination of the physical properties of materials of construction offers a wide field for investigation. In the laboratories at McGill University, results of considerable interest have been obtained as to the magnetic properties of iron at high temperatures, by a new method devised by Professor Callendar. A research on the thermoelectric properties of iron and copper has been made with a view to the accurate verification of the formulas of Avenarius and Tait. A new electrical method of measuring the thermal conductivity of metals is being tried in order to settle the much disputed question as to whether the conductivity is constant or varies with the temperature. An attempt is also being made to verify the very difficult experiments of Lord Kelvin on the existence of the Thomson effect, and to measure the amount.

I had hoped to have read before this section a paper giving an account of an investigation as to the effect of the presence of moisture upon the strength of timber. I have, however, been unable to complete the experiments and have been compelled to postpone the preparation of the paper for the present, but I wish to conclude this address by laying before you the general results which have been obtained.

In a paper read before the Canadian Society of Civil Engineers in 1895, I dealt with the transverse, compressive, tensile and shearing strengths of various Canadian timbers, but I refrained from referring specially to the effect of moisture, for the reason that I was not prepared to accept the general statement, that the strength of timber is materially increased by drying the timber until the whole of the moisture has been removed. It is certainly true and has been long known, that the compressive strength of timber under a steady load is increased—sometimes to an extraordinary extent—by eliminating the moisture, and, it has been assumed, that the tensile, shearing and transverse strengths are also increased, though perhaps to a less extent, the opinion being based, mainly, I believe, on the results of experiments in compression. There are a large number of data as to the compressive strength of different timbers, but they are, with some exceptions, of little value, as they are not accompanied by information, which is absolutely necessary for the purpose of comparison. Thus, it is not stated whether the specimens between which the comparison is made, were in the same continuous line parallel to the axis in the timber from which they were originally cut, a very important factor, as the co-efficients of elasticity and the ultimate strength depend essentially upon the position of the specimen relatively to the heart. As an example of this, it may be stated, that the variation in the direct compressive strength of a Douglas Fir stick was found to be from 2600 lbs. per square inch, near the heart, to 6000 lbs. per square inch, ten inches from the heart. The tensile strength of specimens of the same stick was also found to vary in a like manner.

Neither do the data give sufficient information as to the relative amount of moisture present in the specimens, nor does it seem that any notice has been taken of the effect of the extremes of temperature upon specimens in abnormally wet or dry conditions.

With a view to determining some of these points more precisely, I commenced a series of experiments on hemlock, spruce, red pine and white pine, great care being taken to ascertain the effect of any abnormal conditions on the elasticity and strength of the timber in question.

In the observations I used an Unwin's recording extensometer reading to the 1/100.000th of an inch. I had previously found that with slight variations of temperature, the contraction and expansion of the distance rods of this instrument produced serious errors in the readings, errors, in fact, which often vitiated the whole experiment.

In order to eliminate these errors. I substituted for these rods, wooden rods with light steel plates at the ends. The wooden rods were made impervious to moisture by boiling them in paratine wax until they were so completely saturated that they sank to the bottom. They were then allowed to cool and afterwards properly prepared for the extensometer work. It was found that with these rods the error due to a variation of 1° of temperature did not exceed 1/300,000th of an inch, whereas with the ordinary steel rods the error was fifteen to eighteen times as great. The same extensometer was used both in the tension and in the compression experiments, the scale in the latter case being of course inverted.

For the purpose of obtaining an accurate comparison, the greatest care was taken that the specimens in the original timber were in the same continuous line, and that, consequently. they had the same proportion of hard and soft fibre and were alike in clearness and straightness of grain.

The experiments may be divided into four classes, namely, (1) direct tensile ; (2) direct shear ; (3) direct compressive ; (4) transverse. The conditions of the timber ranged from a frozen and from a saturated condition to a kiln-dried condition. in which the whole of the moisture had been eliminated. The observations as to the effect of freezing and excessive moisture upon the strength of the timber were made on hemlock and spruce specimens only. I shall designate as the normal state that condition in which the specimen contains the greatest amount of moisture consistent with the hygrometric state of the surrounding atmosphere.

The wet specimens used in the present experiments were cut from logs taken from the river, in which they had been submerged for several months, and contained their natural moisture in addition to the water absorbed whilst in the river. When these spruce and hemlock logs were cut through, they were found to be completely saturated and also frozen. Some of the comparative results were obtained from specimens cut from the logs after they had been transversely tested. While still saturated, they were worked into suitable forms with as little delay as possible and as each specimen was made it was buried in snow until required for the test. Many of these specimens were tested when in a frozen condition, others when saturated, but not frozen, and again some were kiln-dried at 212° Fahren., until every trace of moisture had been removed. This point was considered to be reached when repeated weighings showed no appreciable difference. They were then taken out of the kiln and allowed to cool, a necessary precaution in order to eliminate any possible effects of heat on the specimen and extensometer. No sensible change in weight could be detected during the cooling process and the specimen remained apparently devoid of moisture at least long enough to allow of one complete test. As most of these tests were carried on during the winter, at a time when the atmosphere contains a minimum amount of moisture, absorption was not so rapid as at other periods of the year. It was found, nevertheless, that wood is so sensitive to the effect of moisture that advantage was taken of this property to determine the relative humidity of the atmosphere.

I might here remark that it is by no means easy to secure complete saturation by submersion. Indeed, I have found that specimens of spruce and pine, after having been submerged for several weeks, were saturated to a depth of less than one-eighth of an inch. This is a matter of importance in structural work as, if the timber rapidly absorbed moisture, repeated wettings might diminish the compressive strength to such an extent as to endanger the stability of a structure.

TENSION EXPERIMENTS.

Tensile tests of kiln-dried specimens are of value as standards of reference, but inasmuch as the timber gradually tends to pass into what I have called the normal state, the tests made between these two conditions are of no practical value.

As long as a specimen contained no moisture, it was found that the extension was directly proportional to the load, so that the corresponding co-efficient of elasticity could be readily determined. As soon, however, as the specimen commenced to absorb moisture, there ensued, under the same load, a gradual but continuous increase in the extension, until the normal state was reached. At this point the effect of the hygrometric condition of the atmosphere was very marked, the total extension increasing or diminishing with the slightest increase or diminution in the amount of moisture. As a further check, the amount of moisture absorbed by a specimen similar to the one under stress was carefully estimated by frequent readings, and the result showed a variation in weight corresponding exactly with the variation in the extension of the test piece. An additional verification of these results was obtained by carefully mounting another specimen, without subjecting it to any stress except that due to its own weight, and making the observations with a Martens extensometer. The resulting effects were precisely similar to those obtained in the other experiments.

A kiln-dried tension specimen of red pine, with a sectional area of ·658 square inches, was placed in the testing machine on April 10th, and was subjected to a load which was gradually increased up to 1,000 lbs. The extensometer was then adjusted to a zero reading, and observations of the extension in one hundred thousandths of an inch were made. The rate of extension during the first day was 6·1 hundred thousandths of an inch per hour. On every succeeding day this rate diminished, but irregularly, according to the humidity of the atmosphere, until the test piece had attained its normal state. At this point the slightest change in the humidity was reflected in a corresponding change in the extension of the specimen. The maximum amount of extension, viz., ·00708 inch, occurred on the 11th of May. The greatest observed rates of extension and recovery per hour were respectively 7 and 8 one hundred thousandths of an inch. On the 16th of May the load was reduced to 200 lbs., when the amount of the extension was reduced to ·0024 inch. One hour later the reading had fallen to ·00233 inch, but an increase in the humidity then caused a corresponding increase in the extension of ·00017 inch.

When the specimen is saturated above the normal state, it becomes very difficult, if not impossible, to obtain the coefficient of elasticity with any degree of accuracy, on account of the rapid evaporation which necessarily takes place. All the experiments, however, indicate that the presence of an excess of moisture, instead of being detrimental to the tensile strength of the timber, really increases it.

In approaching the ultimate tensile strength it is found that the rate of yielding is much more rapid in proportion to the load, and the greatest care must be exercised in defining the exact point of failure, as it is an exceedingly easy matter to make an error of even as much as 10 per cent. In every case, as might be expected, the coefficient of elasticity is raised by drying.

Shearing Tests.

The experiments in shear show similar results to those in tension, and emphasize even more definitely the fact that the shearing strength of a timber diminishes as it loses its moisture. This diminution of shearing strength has, of course, an important bearing upon the transverse strength, as in many cases it is found that a kiln-dried beam fails from longitudinal shear much sooner than if the beam had been in a normal or even saturated state.

Compression Tests.

Probably over 80 per cent of the timber used in construction is placed so as to be subjected to compressive stress, and for this reason it is most essential to determine the extent to which the compressive strength is affected as the timber passes from a kiln-dried condition to a condition of complete saturation. The tests of kiln-dried specimens are valuable as standards of reference, but as it is impossible to keep timber in a kiln-dried state inasmuch as it gradually tends to pass into the normal state, the tests made between these two conditions are of no practical value.

The kiln-drying of timber increases the compressive strength often as much as 50 to 75 per cent, and in some cases, the strength has even been doubled. A large increase of strength might have been naturally expected, as in the process of drying the walls of the cells are stiffened and hardened and become more able to resist compressive force, but the walls are also made more brittle and it is possible that a sudden blow might result in fracture at a point lower even than would have been the case had the timber been allowed to remain in its normal state.

There are many cases in practice where the timber is alternately wet and dry. These are cases in which the moisture is greater than in the normal condition, and tests at these stages, as well as in the normal and completely submerged conditions, become therefore of great practical value.

The load on a kiln-dried specimen, so long as it does not exceed, say about 60 per cent of the ultimate strength, produces a compression directly proportional to the load, and the element of time seems to be no longer an appreciable factor. The set, too, when the specimen is relieved of load, is very small. The coefficient of elasticity can therefore be readily obtained. As the load increases beyond the 60 per cent, the rate of increase of the compression is much less in proportion to the rate of increase of the load, and the resistance becomes similar to that offered by a hard material like stone. When the maximum load is reached, the specimen fails instantaneously, by breaking up into longitudinal splinters, in some cases as small as match wood.

If the specimen is in the normal state, the amount of the compression is found to vary directly with the amount of moisture present in the atmosphere, and the average coefficient of elasticity can be easily found. When the moisture in the specimen exceeds that corresponding to the normal state, it is difficult if not impossible, to make even an approximate determination ot the coefficient of elasticity. Time now becomes an extremely important factor. The amount of the compression (and the set) increases with, but much more rapidly than, the load, and hence it becomes of the utmost consequence, as the ultimate strength of the specimen is approached, to carefully note the point at which failure actually occurs, as it is quite possible through inexperience, inattention, or by design, to obtain a result which is inaccurate to the extent of 8 or 10 per cent, or even more.

The character of the failure of a wet specimen depends upon its length, its diameter, and upon the proportion of hard and soft fibre. Should there exist any great difference in the density of the annual rings, failure will first be apparent on that side on which the density is least. In long specimens crippling is accompanied by a bending over towards the side of least resistance. In short specimens, failure usually takes place by the folding or crippling of the layers at or near both ends.

TRANSVERSE TESTS.

Transverse tests upon kiln-dried timbers are of importance as standards of reference, but as this condition cannot be maintained, and the timber gradually tends to pass into the normal state, transverse tests taken between the two conditions are of little, if any, practical value.

Since the kiln-drying diminishes the tensile and shearing strengths and greatly increases the compressive strength, an absolutely dry beam, under a transverse load, will fail either by a tensile fracture or by longitudinal shear. Failure on the compression side rarely takes place; only, in fact, when the compressive strength of the wood is very low in comparison with the tensile, and when the proportion of hard and soft fibre is uniformly distributed over the upper and lower halves of the section, may initial failure by crippling be expected.

The question of how far in practice it is desirable to eliminate the moisture depends on obtaining the best balance between the effect on the tensile, shearing and compressive strengths. It should be remembered that drying causes seasoned cracks to become more pronounced, and as frequently these extend to a great depth and run the whole length of the beam, it often happens that only a slight layer is left to hold the beam together. Thus a beam, with such defects, though otherwise sound and clear, offers very little resistance to longitudinal shear, and the beam, in fact, should be regarded as made up of two or more superposed beams. Beams should always be placed so that the relative strengths in tension and compression may be exerted to the best advantage.

The elimination of the moisture naturally makes the beam stiffer and gives it a higher coefficient of elasticity. The deflection is directly proportional to the load so long as the latter is less than about 60 per cent. of the ultimate strength.

When the saturation is greater than that at the normal condition of the timber, that is, the condition corresponding to the saturation of the atmosphere, it will be generally found that the greater amount of moisture is detrimental to the transverse strength because the strength on the compression side of the stick is being rapidly reduced almost to the point of crippling and this weakening is not proportionately balanced by the increase of strength on the tension side. The deflection under a given load is greater and more continuous, and failure results from a less amount of load than would be the case were the timber in its normal condition. Timber of average good quality, under such conditions, would fail naturally by compression until the surface of resistance under compression balances and so overcomes the tensile strength of the remainder of the section, after which failure may occur under tension.

A precisely similar beam containing a normal amount of moisture corresponding to the saturation of the atmosphere, will give much higher results, the coefficients of transverse elasticity and ultimate strength being both much greater. This increase in strength is due to the greater resistance to failure on the compression side produced by the drying.

In order to determine the effect of the moisture upon timbers of large scantling, a Douglas Fir beam 16 feet 4 inches × 15 inches × 6 inches, was placed on supports 15 feet 6 inches apart and loaded with 1,000 lbs. at the centre. At first the deflection of the beam gradually increased and the increase continued for some months until the beam had attained its normal state, when the average deflection remained constant, showing a slight increase or decrease, corresponding to the degree of moisture in the air. The load of 1,000 lbs. was placed on the beam June 15th. 1895, the resulting deflection being ·071 in. On August 24th it was found that this had gradually increased to ·090 in., and from August 24th to September 2nd the deflection ranged between ·090 and ·082 in., according to the humidity of the atmosphere. On September 4th, 1895, the load was increased to 2,000 lbs., the corresponding deflection being ·127 inches. This load was allowed to remain on until January 8th, 1896, and the deflection averaged between ·129 to ·114 in. On January 9th, 1896, the load was entirely released, the observed set being ·025 in.

In the normal state, as in the kiln-dried state, the average deflection was found to be directly proportional to the load.

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